# Linking NASA Satellite Data and Science to Enhance Fire Emissions within the EPA's National Emissions Inventory: Developing Agricultural/Rangeland Fire Emissions Estimates, Connecting Models to Plume Injection Height Data, and Verifying Modeled Emissions Estimates

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**Photo courtesy of Brian Stocks**

**Satellite, coincident aircraft and in-situ field campaign data**

CALIPSO, MODIS active fire & area burned GOES ABBA,
ASTER, MISR, AWiFS and Landsat

**I** **Generate Agricultural and Rangeland Burned Area and Emissions**

**Verify and Validate**

**II** **Generate a lidar-satellite(CALIOP)-derived Fire Plume Injection Height Database**

**III**

**WF-EIS** – web-accessible dataset

**NEI**

**Enhance**

**LAYPOINT module**
**SMOKE** pre-processor

**Decision Support System - CMAQ chemical transport model**
**Benchmark - Spatial and Temporal enhancements**
Comparisons of pre- and post- pollutant concentrations in AQ simulations:
AIRS/Aqua & MOPITT/Terra CO; OMI/Aura – Ozone, MODIS – Aerosol Optical Depth
EPA -- Ground-level concentrations of pollutants

# Motivation

**Smoke from biomass burning contributes to:**

❖ **Decreased visibility - increased regional haze in protected areas;**

❖ **Major contributor of particulate matter (PM), ozone, NOx, VOCs and other pollutants (affects human health);**

❖ **Impedes the ability of regions to achieve National Ambient Air Quality Standards (NAAQS) for PM 2.5 and ozone;**

❖ **Alters the Earth's radiation balance and feedback to climate change (i.e. cloud formation, patterns of precipitation, vegetation change, black carbon on snow and ice).**

1 year after burn

**Linking NASA Satellite Data and Science
to Enhance Fire Emissions
within the EPA's National Emissions Inventory:**

**Goal of Application:** **To demonstrate to our partners, the Environmental Protection Agency (EPA), regions, and states, the value of NASA satellite data and models to their process and Decision Support System.**

Strategy:
(1) To work directly with the customers to understand their needs, not what we 'know' would be best for them;
(2) Demonstrate and prove the enhanced value to their Decision Support Tools with the addition of NASA satellite data and models;
(3) Illustrate the use and applicability of NASA data.

**Linking NASA Satellite Data and Science
to Enhance Fire Emissions
within the EPA's National Emissions Inventory:
Using CALIOP Data to Estimate Fire Plume Injection**

**Task Goal:** Use NASA satellite data and models to demonstrate the potential improvement in fire plume injection height.

Before now, we have not had the ability to accurately estimate fire plume injection height [now MISR (morning only overpass) and CALIOP available].

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# Fire Plume Injection Height
## is important to fully assess.

If we don't get the injection height correct, the transport of pollutants will be incorrectly modeled resulting in:

* a mis-informed public (air quality reports), which could adversely affect human health;

* an inability to accurately assess the Exceptional Events Rule (72 FR 13560, March 22, 2007), which allows the exemption of certain monitored data that are affected by natural exceptional events from consideration when determining a State's NAAQS compliance; and

* inaccurate tracking of elemental carbon, which could have a strong influence on the climate system (BC in Arctic; altered patterns of precipitation; radiation feedbacks from snow/ice, within- above- clouds).

# Fire Regimes Vary Widely



Photo: Conard

Photo: Conard

What burns does matter.

Photos: Stocks and Soja

June 28 2008
Columns near
Lake Athabasca:
5-6 km

Photos courtesy P3 group

**Climate** ➡ **Weather** ➡ **Available Fuel** ➡ **Injection height**

**Fires between Athabasca and Reindeer Lakes**

**June 30 2008**

**5-7 km**

**Photos courtesy P3 group**

**Climate** ➡ **Weather** ➡ **Available Fuel** ➡ **Injection height**

# Typical pyroCb convection columns (10-12 km)



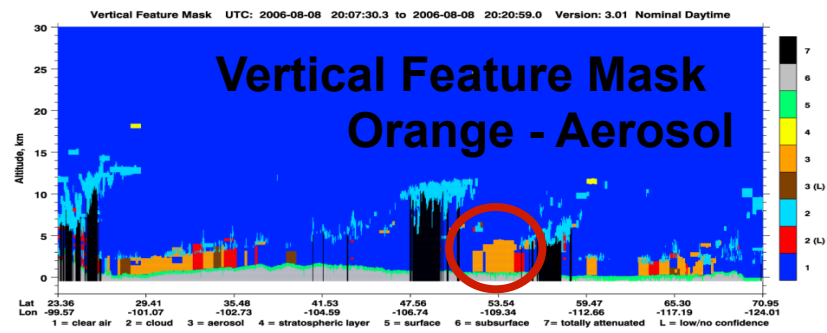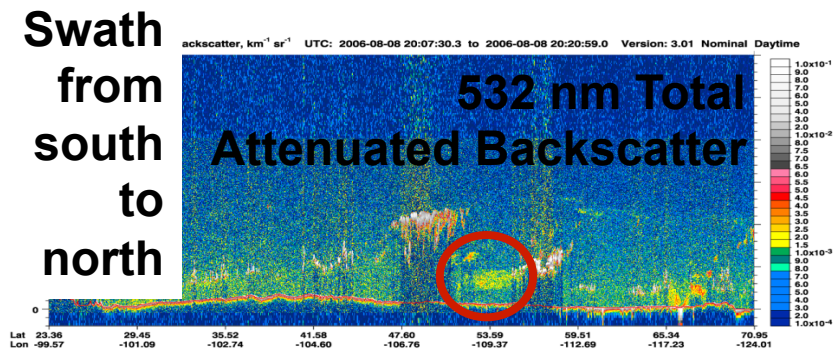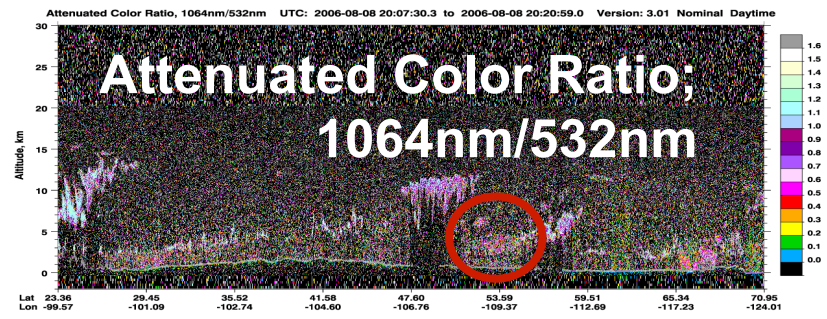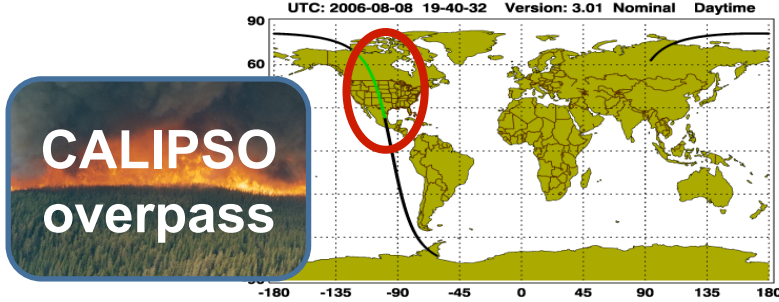**Typical pyroCb fire behavior: continuous high-intensity crown fires**

**Climate ➔ Weather ➔ Available Fuel ➔ Injection height**

# Run LaRC Trajectory Model backward until intersection with MODIS fire detection all in 3-dimensional space and time



## CALIOP Curtains (v3) 08 August 2006 20:07 to 20:20

# CALIPSO Data and Associated Variables

**Active fire size or area burned (source)**
**Number of active fire detections (MODIS Terra and Aqua)**
**Fire radiative power or energy**

**CALIPSO curtains**
**Top, median and bottom of CALIOP plume height**

**IGBP vegetation 1km MODIS**
**Elevation**
**Available fuel**

**Air parcel counts , mean range**

**Relative Humidity (2m, 10m)**
**Temperature (2m, 10m)**
**Wind speed and direction**
**Precipitation**
**Fire weather (Haines, CFFWIS ?)**
**Time of day (solar zenith angle?)**
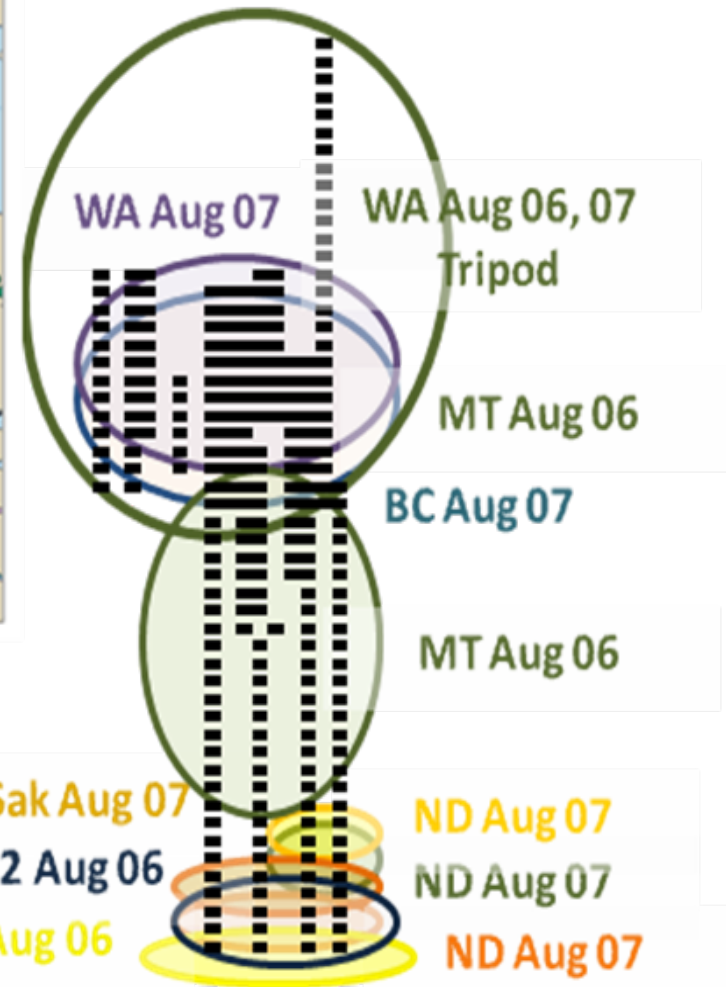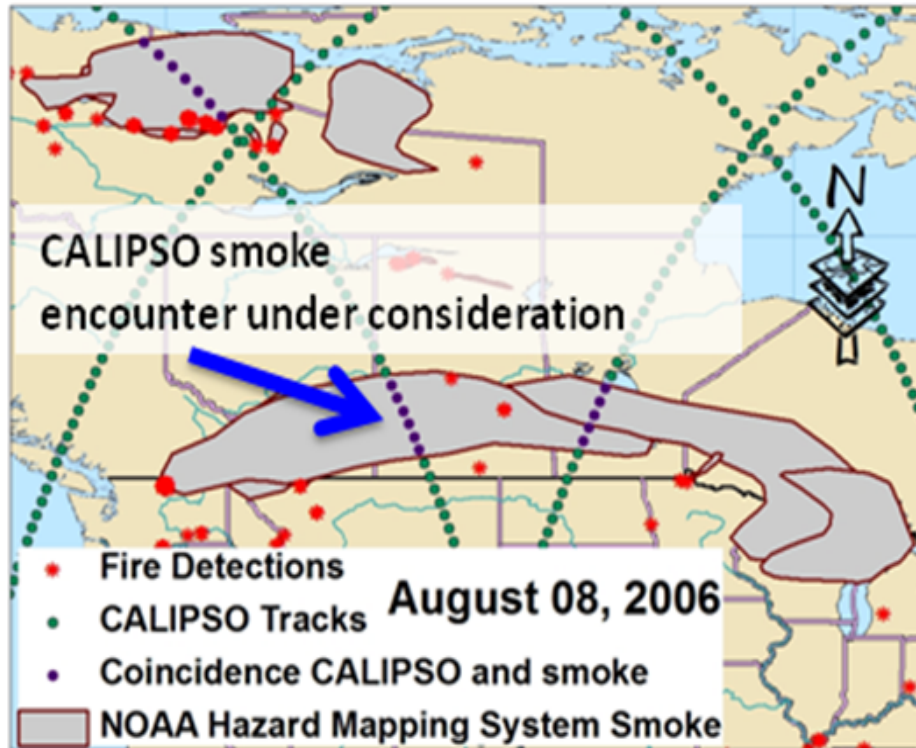**Atmospheric soundings (radiosonde NWS – normal 0z 12z and fire weather; GOES-5**
**PBL**
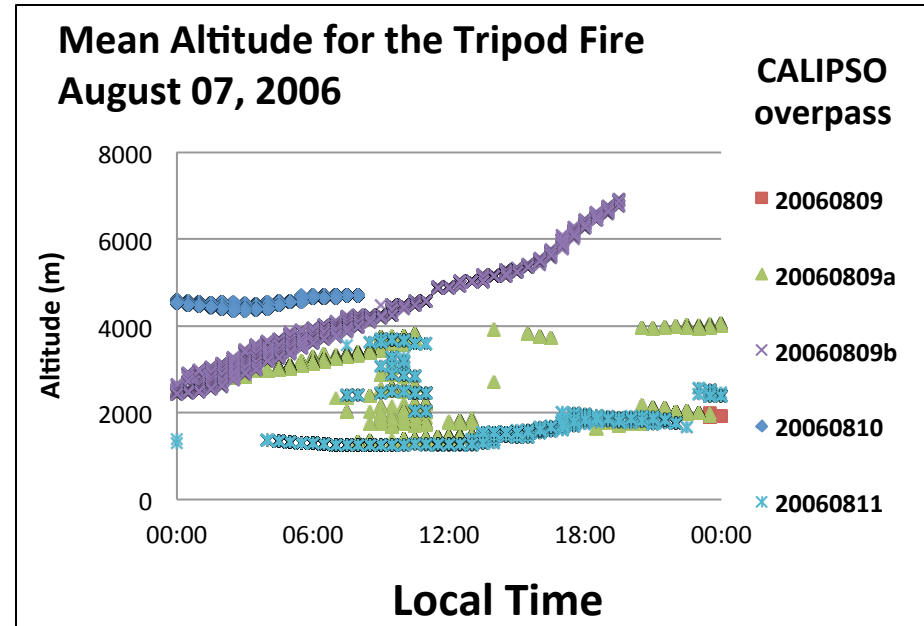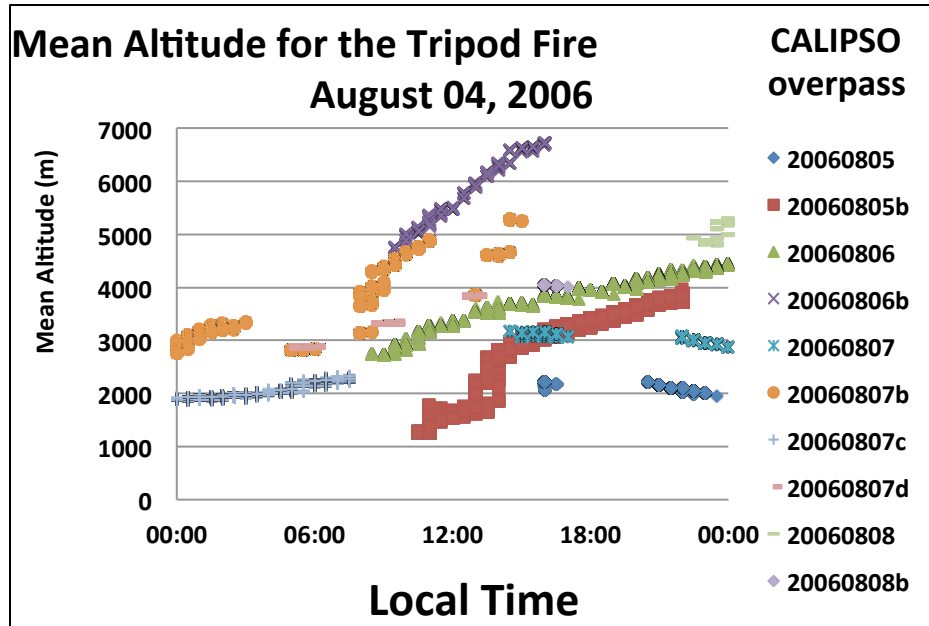
**Latitude/longitude fire location and plume**
**FIPS**
**Fire name**

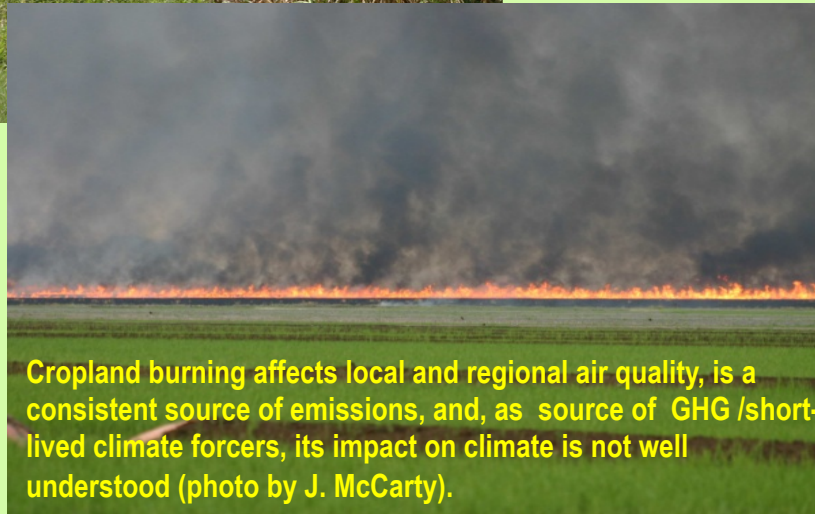# This plume can be attributed to 7 unique fires on 9 different event days.

# Daily evolution of fire plumes from specific fires.



**Mean Altitude for the Tripod Fire
August 04, 2006**

CALIPSO overpass
- ◆ 20060805
- ■ 20060805b
- ▲ 20060806
- ✕ 20060806b
- ✕ 20060807
- ● 20060807b
- ✚ 20060807c
- ▬ 20060807d
- ▬ 20060808
- ◆ 20060808b



**Mean Altitude for the Tripod Fire
August 07, 2006**

CALIPSO overpass
- ■ 20060809
- ▲ 20060809a
- ✕ 20060809b
- ◆ 20060810
- ✕ 20060811





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# Cropland Burning



Cropland burning affects local and regional air quality, is a consistent source of emissions, and, as source of GHG /short-lived climate forcers, its impact on climate is not well understood (photo by J. McCarty).

# Work with customer to establish a comfortable data relationship
## Comparison of PM2.5 from a variety of products, annually over CONUS, EPA Region 4 and EPA Region 8.
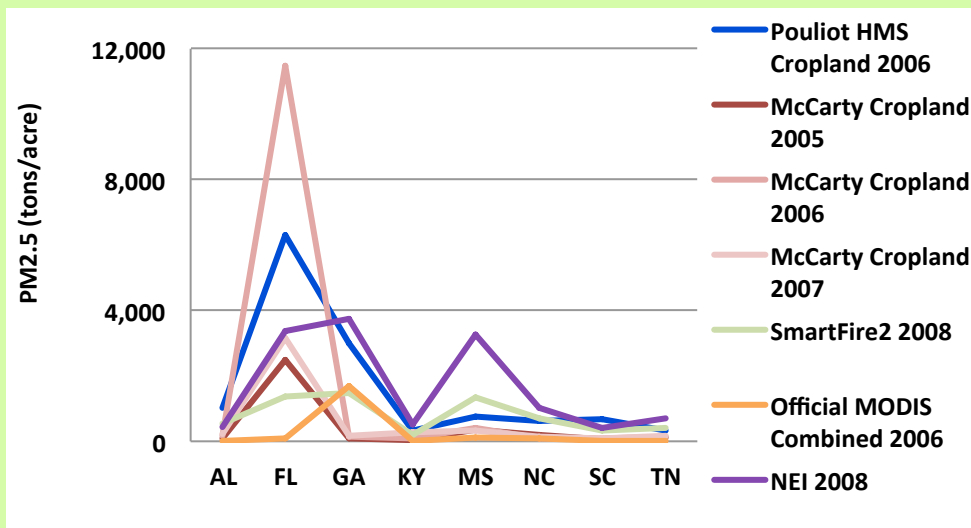
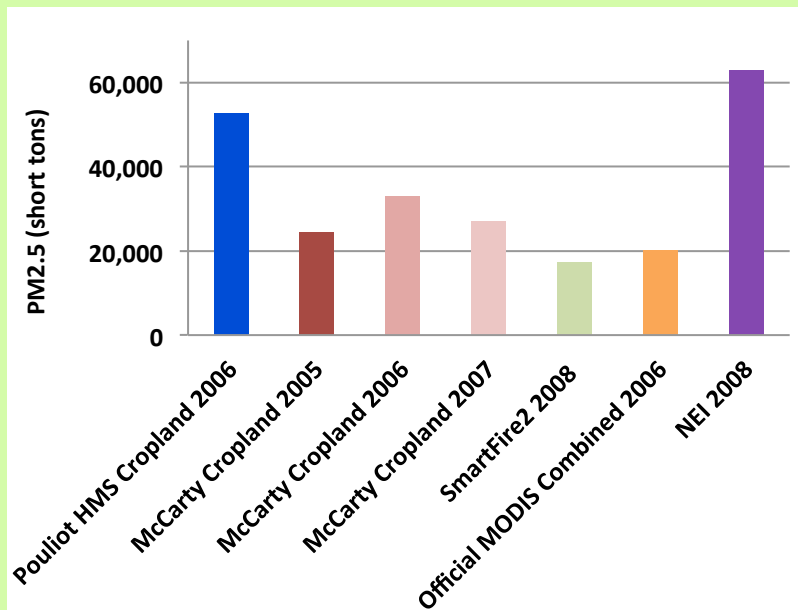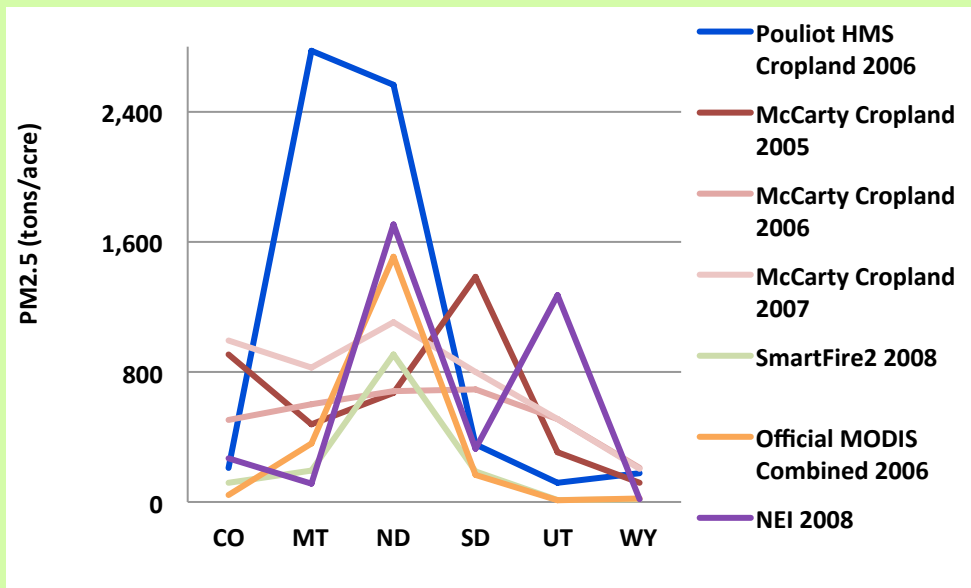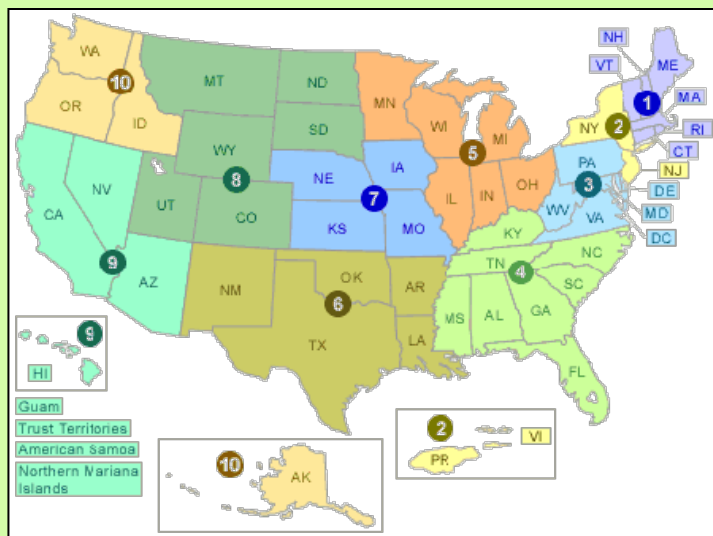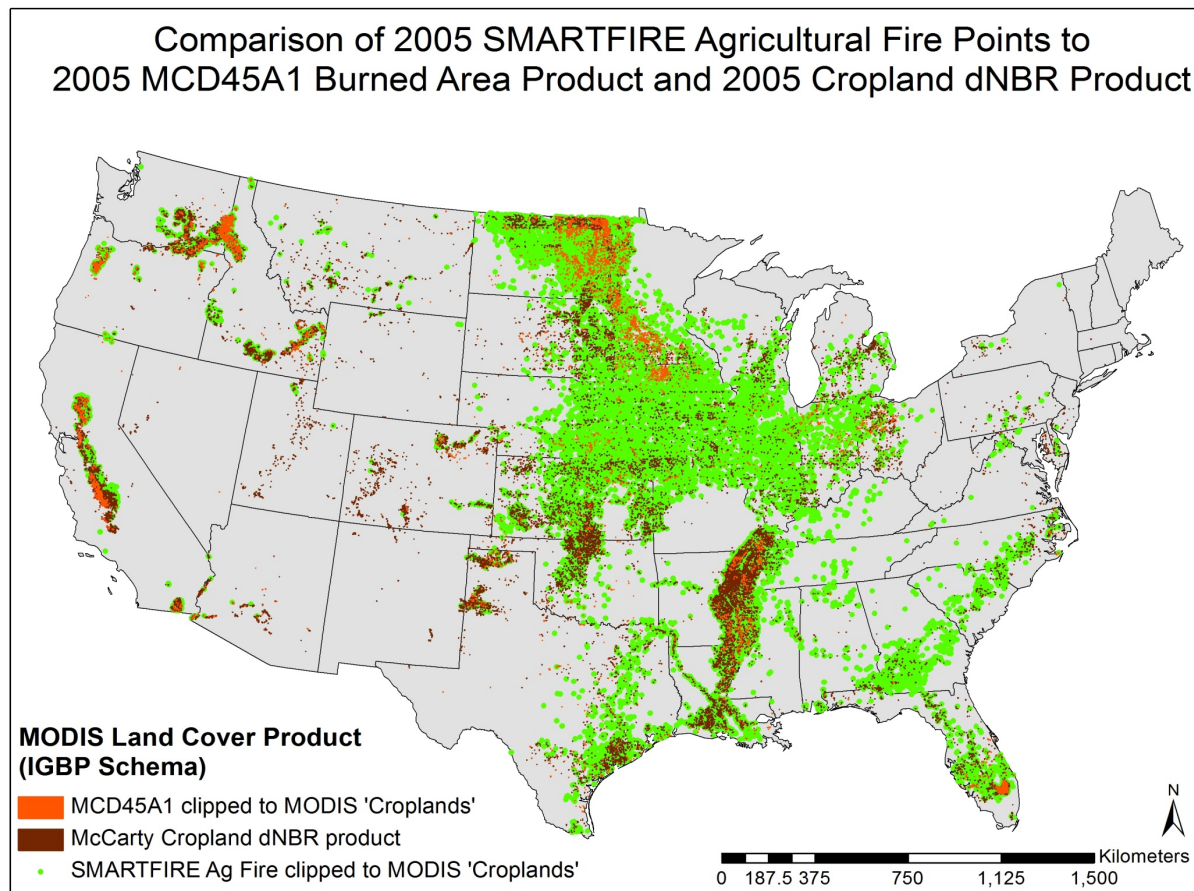**Goal: Use NASA satellite data to demonstrate the potential improvement to our National Fire Emission Inventory (NFEI) by using NASA data.**
**Second Larger Goal: Integrate NASA data into the permanent NFEI process.**

**Only 51% of 'agricultural' fires in SMARTFIRE occurred in agricultural areas as defined by MODIS Land Cover data. Approximately 9% of cropland burned area product was spatially contiguous (within 1 km) to the 2005 SMARTFIRE 'Agriculture' points.**



Comparison of 2005 SMARTFIRE Agricultural Fire Points to
2005 MCD45A1 Burned Area Product and 2005 Cropland dNBR Product

**MODIS Land Cover Product (IGBP Schema)**
- MCD45A1 clipped to MODIS 'Croplands'
- McCarty Cropland dNBR product
- SMARTFIRE Ag Fire clipped to MODIS 'Croplands'

Kilometers
0   187.5  375      750      1,125      1,500

# Linking NASA Satellite Data and Science to Enhance Fire Emissions within the EPA's National Emissions Inventory:

## Enhancing Biomass Burning Emission Inventories with a Focus on Croplands and Rangelands

## OBJECTIVES

- **Utilize NASA satellite data to improve air quality and human health.**

- **Determine accuracy, effectiveness, and suitability of currently available satellite burned area products for sources of emission estimate from crop residue and rangeland management burning.**

Cropland burning affects local and regional air quality, is a consistent source of emissions, and, a source of GHG /short-lived climate forcers, its impact on climate is not well understood (photo courtesy of Jessica McCarty).



## APPROACH

- Datasets compared include SMARTFIRE (Raffuse et al., 2009), the MODIS Official Burned Area Product (MCD45A1) (Roy et al., 2005), the MODIS Active Fire Product (MOD/MYD14) (Giglio et al., 2003), and the regionally-tuned 8-day cropland differenced Normalized Burn Ratio product for the contiguous U.S. (McCarty et al., 2008).

- Integrate the 8-day and daily combined cropland burned area products into the Sparse Matrix Operational Kernel Emissions (SMOKE) system and the Community Multiscale Air Quality (CMAQ) model.

## MAJOR MILESTONES TO DATE

- Found spatial inconsistencies with current EPA cropland burning inventory (2005 SMARTFIRE compared to McCarty 8-day product);

- Comparison between combined daily product with McCarty cropland burned area product showed good spatio-temporal agreement and moderate agreement in quantity of emissions. Developed daily hourly fire probability for cropland fires based on field work performed by McCarty and Giglio (2007).

- **MODIS-based cropland emissions are being used in our National Emissions Inventory, available nationally and individually accepted by states.**

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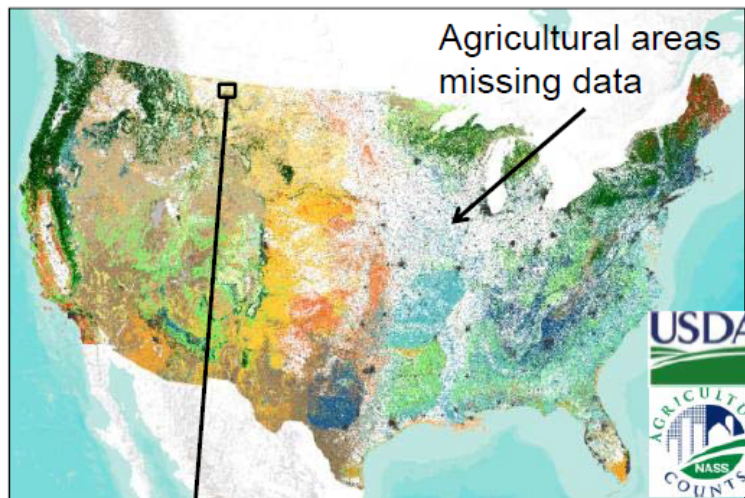
# Linking NASA Satellite Data and Science to Enhance Fire Emissions within the EPA's National Emissions Inventory:

## Enhancing Biomass Burning Emission Inventories with a Focus on Croplands and Rangelands



**Integration of Cropland burning:**
Filling in the Gaps with the Cropland Data Layer

Agricultural areas missing data

Status:
- Fuels descriptions (FCCS fuelbeds) and maps for 2009 & 2010 completed
- Crop fuels consumption data integrated into WFEIS
- Next step is to integrate fuels into WFEIS & roll out ability for queries across CONUS
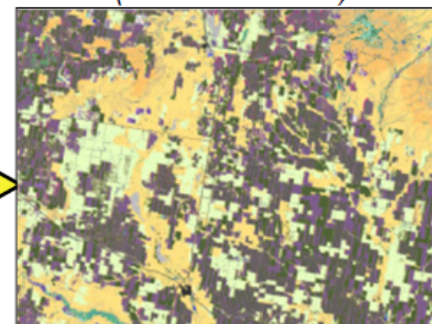
Merged FCCS/CDL Layer (30m resolution)

FCCS (30m resolution)

CDL (30m resolution)

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# Application Readiness Level

**Cropland burned area and emissions** have been verified, validated and integrated into the EPA's Decision Support System (DSS), the National Emissions Inventory (NEI), however rangelands have not. Several states have already used the average cropland data from 2003- 2007 in the 2008 NEI, and the final national 2011 NEI is expected have the McCarty data available for the official national cropland fire emissions input to the NEI, to be accepted individually by states.

**PHASE III, ARL level 9**

Issue - However this likely will not be sustained (state challenges).

Fix - Jessica has submitted to the New Investigator program and an IDS. Sonoma is also interested.


The **WF-EIS tool** itself is reported to be at an ARL level 5 and is currently on-line and being used, but it is still considered a demonstration site. Closely worked with both the USDA Forest Service and our EPA partners (<u>update land cover codes</u>). Cropland data are being served at WFEIS. The **cropland portion of WFEIS** that falls under this task is at an **ARL level 5**.

<u>Bonus</u>- Generated (with EPA and USDA Forest Service), mapped and integrated the cropland FCCS information across CONUS. - **ARL level 9**

Issue – Differing resolutions of the products. Jessica's and the CONUS FCCS fuel map (30m) and other emissions and satellite data (1km).

Fix - Will be serving the computed emissions files, like have been created for and provided to the EPA.

# Application Readiness Level

The **CALIOP-based plume injection height** data exist in the domain between Phase I and II, having addressed aspects of **ARL 3 and 4**.

We have worked with several DSS partners to ensure applicability, making certain to include the aspects of plume injection height that are important to the DSS.  However, the technical process is time consuming and complicated and few datasets are available for verification.

It is this dataset that the smoke community would like to use to verify their products.  When developed, these data have the potential to become sustained at an ARL level 9, active within numerous national and international organizations, if supported under additional research and application calls.

Issue - Loss of key personnel early in project  (replacements overwhelmed);
- Lost CALIPSO CloudSat re-compete

Fixes - Acquired 1-year no-cost extension
- 2 people working on this project for the next few months;
- Have secured limited funding from CALIPSO; and
- Hope to be able to highlight the progress of this work next year, if funding and space allows, as a community friend.

# Costing

**National Institute of Aerospace (NIA - Soja)**
     **portion of the budget**
As of August 31, 2013
     - $37,700 uncosted out of $220,936
     **Michigan Technical University**
     **(French and McCarty)**
     **should be fully costed now;**

**NASA portion of the budget**
**NASA Langley Research Center (Fairlie)**
     **Fully obligated – uncosted**

| Budget | Obligated | Unobligated | Costed | Uncosted |
|--------|-----------|-------------|--------|----------|
| 109,081 | 102,792 | 6,289 | 10,737 | 98,344 |

**Fireweed
1 year after burn**

## Concluding Thoughts

Our team is quite proud of its accomplishments, in terms of:
- (1) having gained trusted relationships that will continue; and
- (2) in the application of NASA satellite data and models to active use in Decision Support Systems in regions and states.

- Provided cropland fire emissions data to the EPA for the 2008 and 2011 NEI;
- Trained a variety of regions to calculate on-the-fly emissions;
- Updated FCCS codes for continual use; and
- Proven the feasibility of the CALIOP plume injection height data.

Community note, consideration and conversation (Future – VIIRS):
Organized session at the EPA's International Emissions Inventory Conference (EIC)  ** Invited Louis Giglio as an Expert Biomass Burning (BB) panel member  to discuss state of MODIS and VIIRS;

## Thank-you for your attention.